The Effect of Surface Curvature and a Gel Liner Interface on Performance Properties of the Tekscan F-Socket System

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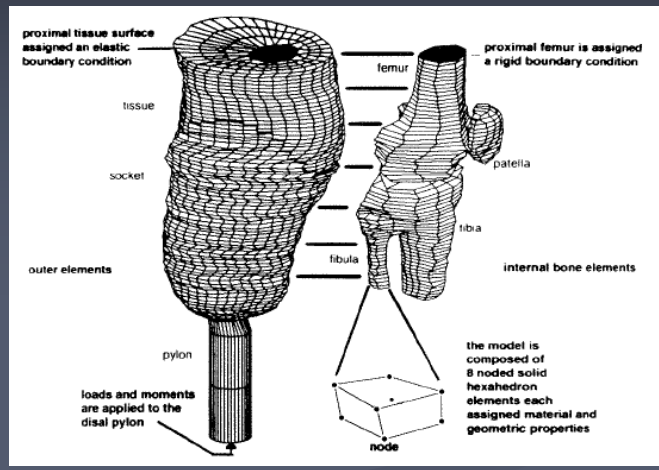
Background

- The presence of mechanical loads at the limb socket interface is considered an initiating cause of tissue breakdown and ulceration (Kosiak 1959, Polliak 2000)
- Prosthetists have historically relied on past experience, patient feedback, and indirect indications of load to gauge socket fit
- Clinical measurement of interface pressures has the potential to provide quantitative, objective information to help in the evaluation of prosthetic fit (Silver-Thorn 1996)

Background

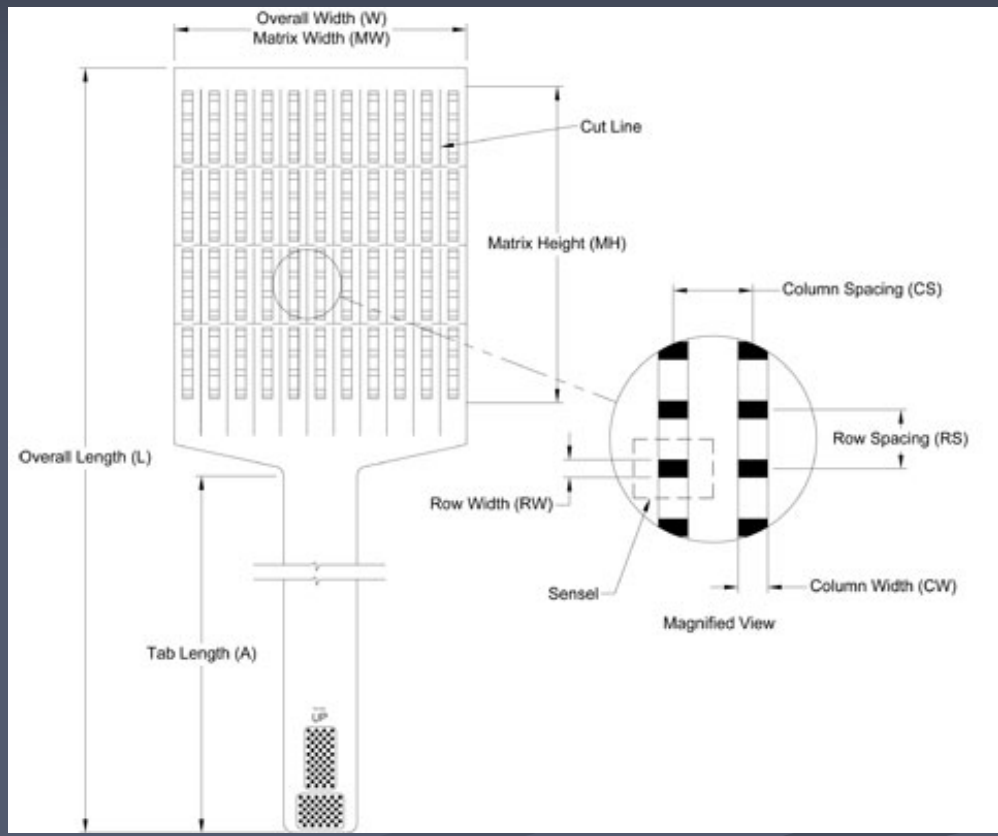
- Finite Element Analysis
- Force transducers
- Force Sensitive Resistive Sensors

(Portnoy 2007, Polliak 2000, Polliak 2002)



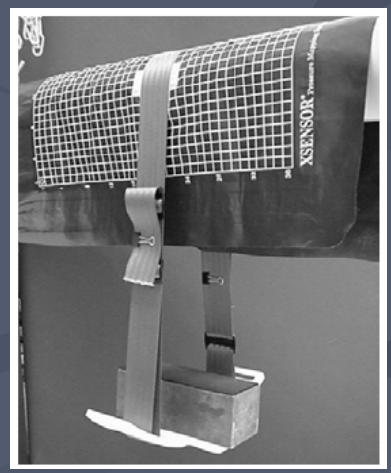
Background

- F-Socket by Tekscan
  - Force Sensitive Resistive sensor
  - 7.43 x 8 inch matrix
  - 11 columns
  - 16 rows
  - 176 sensels
  - 2.96 sensels / in^2



Background

- Research examining Tekscan FSR properties such as accuracy, hysteresis, and drift have been performed on flat and contoured models



(Polliak 2000, Polliak 2002, Fergenbaum)

Background

- Tests have not been performed using axial loading and a gel liner to more closely simulate a clinical setting

Hypotheses

- Drift and cyclic drift errors will be affected by the presence of a gel liner.
- Drift and cyclic drift errors will be greater over a curved surface than a flat one.

Design and Methods

- F-Socket sensor #9830
- Instron Servo-Hydraulic Testing Machine
  - Flat indentor
  - Round indentor (r = 6.5cm)
- Calibration performed to 10 psi according to manufacturers procedure prior to each testing session
- 6mm uniform cushion Alps silicone gel liner material

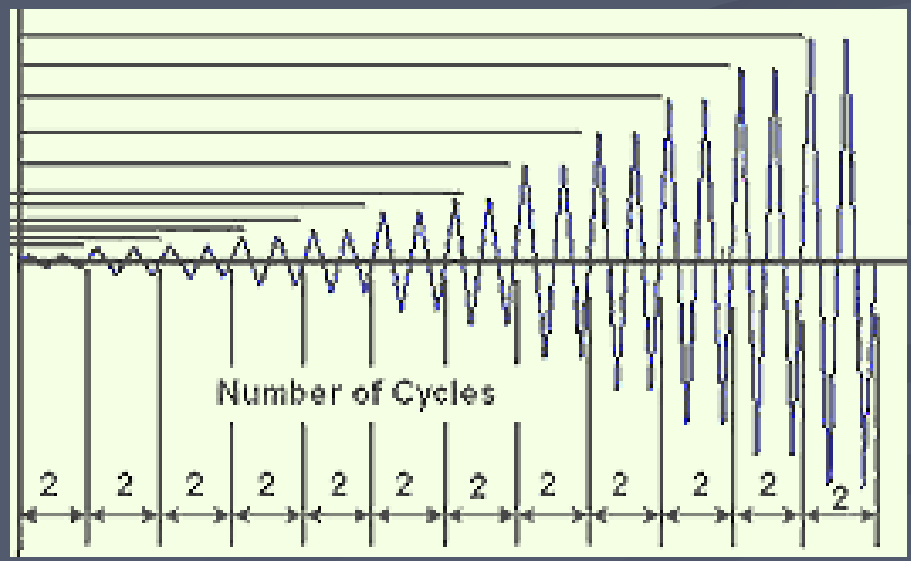
Design and Methods

- Drift
  - Hold for 20 min
  - Take samples at 1, 5, 10, 15, and 20 minutes
  - Perform at 5 psi
  - $D_E = [(SR_0 – SR_{(x)}) / SR_0] \times 100$

Polliack (2000)

Design and Methods

- Cyclic Drift
  - Cycle from 2 → 8 psi for 10min
  - Record 10 trials at 1, 5, and 10 min
  - $D_E = [(SR_0 – SR_{(x)}) / SR_0] \times 100$



Buis (1997) Polliack (2000)

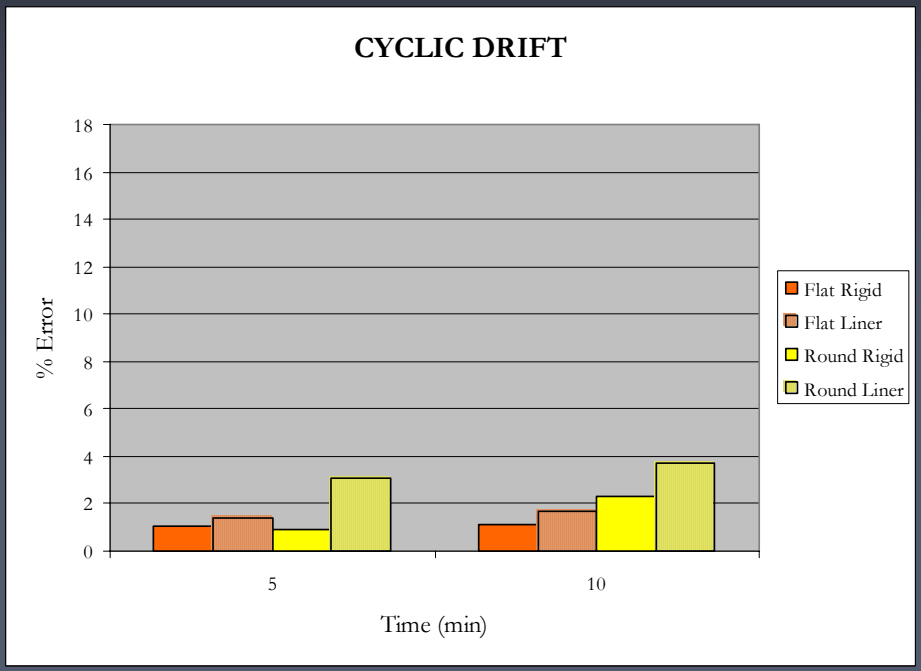
Design and Methods

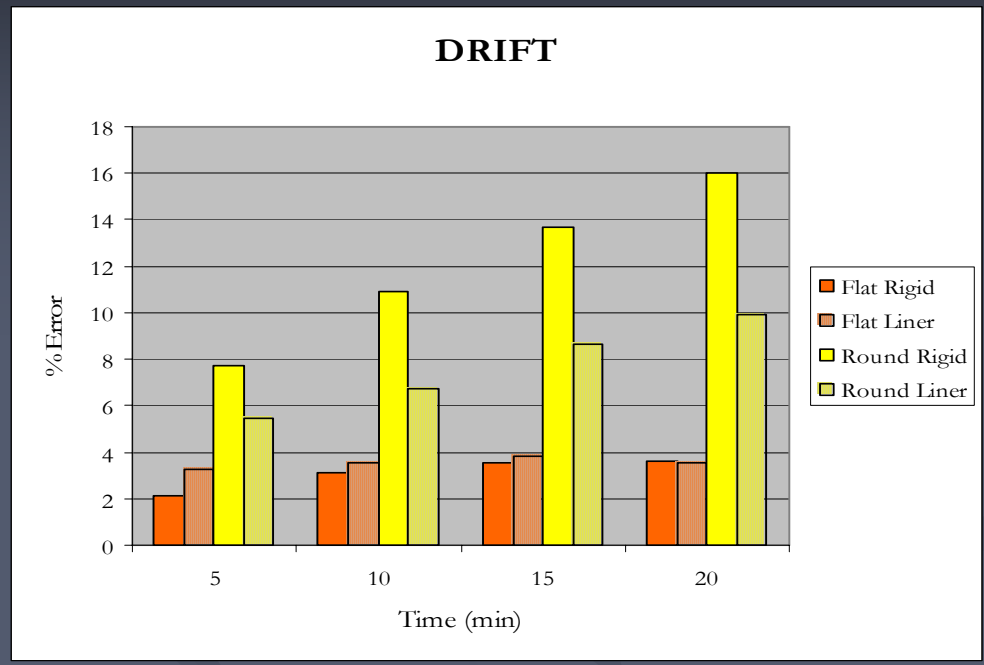
- Each test performed under four conditions
  - Flat indentor / rigid interface
  - Flat indentor / gel liner interface
  - Spherical indentor / rigid interface
  - Spherical indentor / gel liner interface

Design and Methods

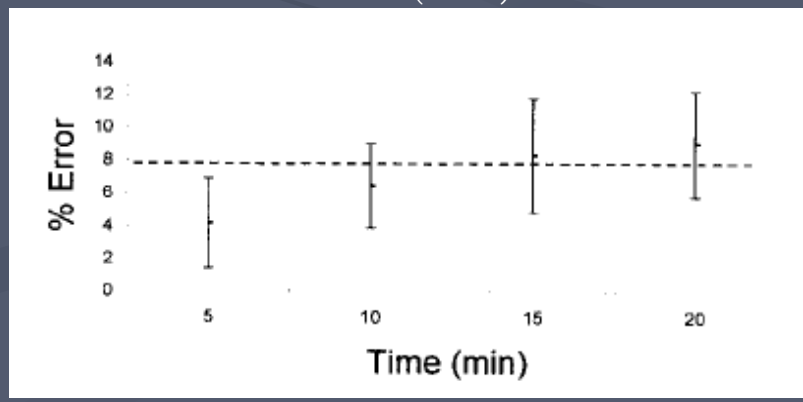
- Independent variables
  - Indentor shape
  - Interface material
- Dependent variables
  - Drift Error
  - Cyclic Drift Error

Results





Polliack (2000)



Results

- Statistical Analysis
  - Factorial Analysis of Variance (ANOVA)
  - 2x2 – Indentor shape x Interface material

Drift P-values		
Time	**Curvature**	**Liner**
5	0.003023083	0.747187
10	0.000308661	0.509978
15	2.17615E-05	0.381132
20	3.29076E-06	0.257814

Cyclic Drift P-values		
Time	**Curvature**	**Liner**
5	0.122999057	0.042529
10	0.086581228	0.12346

Hypotheses

- Drift errors will be affected by the presence of a gel liner.
- Drift errors will be greater over a curved surface than a flat one.
- ? Cyclic drift errors will be affected by the presence of a gel liner.
- Cyclic drift errors will be greater over a curved surface than a flat one.

Limitations

- Only one type of liner material was tested
- Only one radius of curvature was tested
- Small sample size

Further Study

- Test with multiple liners
- Test different curvatures
- Test other sensor properties
  - hysteresis

References

1. Buis, A. and P. Convery, *Calibration problems encountered while monitoring stump/socket interface pressures with forve sensing resistors: techniques adopted to minimize inaccuracies.* Prosthetics and Orthotics International, 1997. **21**: p. 179-182.
2. Covey, S., J. Muonio, and G.M. Street, *Flow Constraint and Loading Rate Effects on Prosthetic Liner Material and Human Tissue Mechanical Response.* Journal of Prosthetics and Orthotics, 2000. **12**(1): p. 15.
3. Faustini, M.C., et al., *Design and analysis of orthogonally compliant features for local contact pressure relief in transtibial prostheses.* Journal of Biomechanical Engineering-Transactions of the Asme, 2005. **127**(6): p. 946-951.
4. Fergenbaum, M., et al., *Pressure Measurement Applications for Humans*, School of Rehabilitation, Queens University: Kingston, Ontario, Canada.
5. Ferguson-Pell, M., S. Hagisawa, and D. Bain, *Evaluation of a sensor for low interface pressure applications.* Medical Engineering & Physics, 2000. **22**(9): p. 657-663.
6. Houston, V., et al. *Preliminary Results with the DVA-Tekscan BK Prosthetics Socket / Residual Limb Stress Measurement System.* in *American Academy of Orthotists and Porosthetists Annual Meeting and Scientific Symposium.* 1994. Nashville, TN.
7. Hsiao, H.W., J.H. Guan, and M. Weatherly, *Accuracy and precision of two in-shoe pressure measurement systems.* Ergonomics, 2002. **45**(8): p. 537-555.
8. Krouskop, T.A., et al., *Interface Pressures in above-Knee Sockets.* Archives of Physical Medicine and Rehabilitation, 1987. **68**(10): p. 713-714.
9. Polliack, A.A., et al., *Laboratory and clinical tests of a prototype pressure sensor for clincial assessment of prosthetic socket fit.* Prosthetics and Orthotics International, 2002. **26**(1): p. 23-34.
10. Polliack, A.A., et al., *Scientific Characterization of the Rincoe Socket and Tekscan F-Socket Interface Pressure Measurement Systems: Implications for Clinical Utility*, Rancho Los Amigos Medical Center, Rehab Engineering Program. p. 2.
11. Polliack, A.A., et al., *Scientific validation of two commercial pressure sensor systems for prosthetic socket fit.* Prosthetics and Orthotics International, 2000. **24**(1): p. 63-73.
12. Portnoy, S., et al., *Real-time patient-specific finite element analysis of internal stresses in the soft tissues of a residual limb: A new tool for prosthetic fitting.* Annals of Biomedical Engineering, 2007. **35**(1): p. 120-135.
13. Sanders, J.E., et al., *Testing of elastomeric liners used in limb prosthetics: Classification of 15 products by mechanical performance.* Journal of Rehabilitation Research and Development, 2004. **41**(2): p. 175-185.
14. SilverThorn, M.B., J.W. Steege, and D.S. Childress, *A review of prosthetic interface stress investigations.* Journal of Rehabilitation Research and Development, 1996. **33**(3): p. 253-266.
15. SilverThorn, M.B. and D.S. Childress, *Parametric analysis using the finite element method to investigate prosthetic interface stresses for persons with trans-tibial amputation.* Journal of Rehabilitation Research and Development, 1996. **33**(3): p. 227-238.
16. Woodburn, J. and P.S. Helliwell, *Observations on the F-Scan in-shoe pressure measuring system.* Clinical Biomechanics, 1996. **11**(5): p. 301-304.

Thank You

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